Hot Water Recirculation

Pilot Study

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Santa Clara Valley Water District

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Hot Water Re-circulation Pilot Study

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SUMMARY

The Santa Clara Valley Water District, continuously looking for ways to conserve its limited water supply, was awarded $26,000 in grant funding from the Bureau of Reclamation to supplement a Hot Water Re-circulation Pilot Study. The study, which was implemented in February of 2000, had been designed to address both the amount of water savings attributed to these systems as well as what the public's overall perception may be.

Two complementary methods were used. The first method, or Phase I, involved analysis of pre and post installation of water use data for 65 residential participants while the second method, or Phase II, included the use of flow trace analysis (i.e. data loggers and software) for 9 residential participants – a total of 74 homes were included in the study.

A two tailed T test was used to determine the amount of savings in each phase. For Phase I, average household water use decreased by a little more than 2% (approximately 8.6 gallons per day) in the treatment year (July, '00 – June, '01) relative to the control year (July, '99 – June, '00). In Phase II, discretionary water use decreased by 0.6 gallons per person per day following installation of the systems. ***However, neither of these differences (Phase I or Phase II) is considered statistically significant.***

The existence of a non-significant trend toward reduced water consumption may be attributed to several factors, including; small sample size (Phase II), short study time (Phase II) or times per day each participant activated their system. On average, each system was only activated 3 times a day (with only a slight increase when winter months included), far below what the manufacturers promote. This may be due to a lack of education on the participant's part.

Although the majority of participants were satisfied with their system, average rating of 4.3 (on a scale of 1 to 5, with 5 being the high), the lack of statistical significance ***may*** be a reflection of the weakness of these devices as a tool to reduce consumption. Other studies which are currently underway, including the City of Palo Alto's, may provide a more comprehensive (or complimentary) look at the effectiveness of the hot water re-circulation system.

Santa Clara Valley Water District
Hot Water Re-circulation Pilot Study

I. BACKGROUND

As population growth continues its upward trend throughout California, the demand placed on its water supply is also amplified. Each year, California homeowners allow an estimated 120 billion gallons of water to run directly into their sewer lines while waiting for hot water to arrive at showers and sinks. Every gallon of water that enters their home requires energy and processing, and each gallon that goes through their water heater requires additional energy. As a leader in water conservation, the Santa Clara Valley Water District (SCVWD) is continuously looking for ways to conserve its limited water supply. Besides being a signatory to the California Urban Water Conservation Council's Memorandum of Understanding, SCVWD is continuously researching new technologies and/or techniques, one being the Hot Water Re-circulation System.

To date, there are several reports available describing hot water re-circulation systems and the ***potential*** water and energy savings available. One such report, Reference Document: Program Design Tool and Savings Estimates[1], showed water savings of approximately 28.1 gallons per unit per day. This potential water savings was calculated by multiplying the average "cold start" hot water run times with the average savings per run. It should be noted that this study included a "plumbing factor" which offsets the fact that not all of the homes will experience 100% potential savings. Other reports, developed by the manufacturers, have shown similar results using similar methodology. Although such reports provide an important initial look at hot water re-circulation systems, SCVWD decided to go a step further and calculate what the ***actual*** (or field tested) savings may be.

In February 2000, SCVWD began implementation of a Hot Water Re-circulation Pilot Study. The District applied for and was awarded $26,000 in grant funding from the Bureau of Reclamation to help offset the costs of the study. Agreements were also made with the manufacturer of the system as well as a third party to develop the monitoring equipment to be used. Initially, two issues were to be addressed; how much savings can be attributed to hot water re-circulation systems (both in terms of water as well as energy) and what was the public's overall perception of these systems.

[1] Prepared by A & N Technical Services, Inc. 1996

II. STUDY DESIGN

After looking over several options, SCVWD decided on a re-circulation system manufactured by ACT, Inc. Metlund Systems. This system, which works on demand, is designed to be installed under the sink furthest from the hot water heater. When activated (by a push of a button), cool water that normally would go down the drain is circulated back to the water heater through the cool water line. At the same time, the system fills the hot water line with hot water from the water heater. When hot water reaches the system, the zone valve closes and the pump shuts off automatically.

Figure 1: Example of a hot water re-circulation device installed under a sink (photo supplied by ACT, Inc. Metlund Systems)

SCVWD proposed that two complementary methods be used to evaluate the impact of this technology. The first method, or Phase I, involved analysis of pre and post installation of water use data (for 90 residential participants) while the second method, or Phase II, included a more intensive monitoring system (for 10 residential participants). Phase II was also going to look at any possible energy savings that may exist. Analysis of both phases used a two tailed T test to determine the amount of savings attributable to these systems.

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Phase I

Initially, the study was designed for SCVWD to offer a rebate ($200) to entice potential participants. However, it was decided at a later date that in order to efficiently obtain the preferred participants, SCVWD would need to purchase the system and distribute it for free (participants would still be responsible for the installation). Over 1,300 direct mailings, which included a cover letter and an informational flyer, were randomly mailed to potential participants. Interested residents were instructed to call SCVWD and were asked the following questions:

- Number of years at current residence?
- Number of residents?
- Age of house?
- Square footage of house?
- Own or Rent?
- Do you have an existing system?
- Current wait time for hot water?
- Any renovations completed within the last year?
- Any renovations planned in the next year?
- Approximate distance from hot water heater to furthest fixture

Since the goal was to compare a year of pre-installation data to a year of post-installation data of an average home in Santa Clara County, certain participants/homes had to be excluded. For instance, if they had recently installed a new landscape (or were planning to within the next year) they were excluded. Similarly, if the participant had either not resided at their current address for at least a year or if they were a renter (thus more likely to leave before the year of post-installation was over), they were also excluded.

Table 1: Sample Customers Excluded From Study

CUSTOMER ID#	REASON EXCLUDED
5820	New landscape
5630	Less than 1 yr residency
5813	Short wait time for hot water
2490	Adding a new lawn
2544	Renter
5240	Existing re-circulation system

Close to 300 people responded with an initial phone call to SCVWD, with approximately 135 of them completing a phone survey. Once the initial screening was completed, participants still remaining were contacted and a site visit was scheduled. At that point, a SCVWD representative visited the participant's home, took some initial measurements (including the actual wait time for hot water) and dropped off their free system. The participants were also given a waiver, which explained they had one month to have the

system installed or return it (or $250) to SCVWD. The following data was collected at the site visit:

- Number of low-flow fixtures (toilets, showerheads, aerators and washing machines)
- Size of landscaped area
- Size of turf area
- Automatic sprinklers
- Hot water heater temperature setting
- Measured wait for hot water (at the furthest fixture)
- Type of piping (copper, galvanized or PVC)

Phase II

SCVWD initially wanted to address both the water savings associated with these systems as well as any energy savings that may exist. SCVWD had discussions with a third party for them to develop the monitoring equipment needed. This equipment consisted of two parts, a Meter Panel (which was mounted on a plywood board) as well as a Tee and thermocouple. The Meter Panel (which included three flow meters and two check valves) was to be installed at the cold water main line "split" to the water heater while the Tee and thermocouple were to be installed on the hot water line from the water heater. The check valves on the Meter Panel allow water to flow in only one direction, thus enabling the flow meters to register total re-circulated water, the hot water consumption and the cold water consumption. The flow meters were also modified (by combining them with two thermocouples) so that energy use could also be measured.

Since this phase was a much more comprehensive look at the impact of this system, it was designed for only 10 participants. Potential participants were selected in a similar fashion as in Phase I (close to 50 direct mailings were sent out) and were given both a free system as well as the installation of said system. By signing up for this phase, the participants also agreed that SCVWD staff would come to their home once a month (for one year) to read the flow meters on the Meter Panel. The data collected would then be sent to the third party for analysis.

Once the 10 customers were selected, a private contractor was hired to install both the re-circulation system and the monitoring equipment. However, several problems arose with the first installation and because of this, SCVWD decided to look at an alternative approach. Instead of using the monitoring equipment for these ten customers, SCVWD decided to use flow trace analysis (i.e. data loggers and software).

Although energy use (and any savings) was not being measured now, data loggers do represent a comprehensive look at water use. Data loggers record magnetic pulses from the water meter every 10 seconds. These pulses are then converted into a flow rate based on the brand, model and size of the meter. Using the software, a consistent flow pattern can now be isolated, quantified and categorized. Uses such as flushing a toilet or turning

on a bathroom faucet can be identified and measured. Because of this, all water used by a single family residence can be accounted for, thus enabling the SCVWD to quantify the effects of these hot water re-circulating systems.

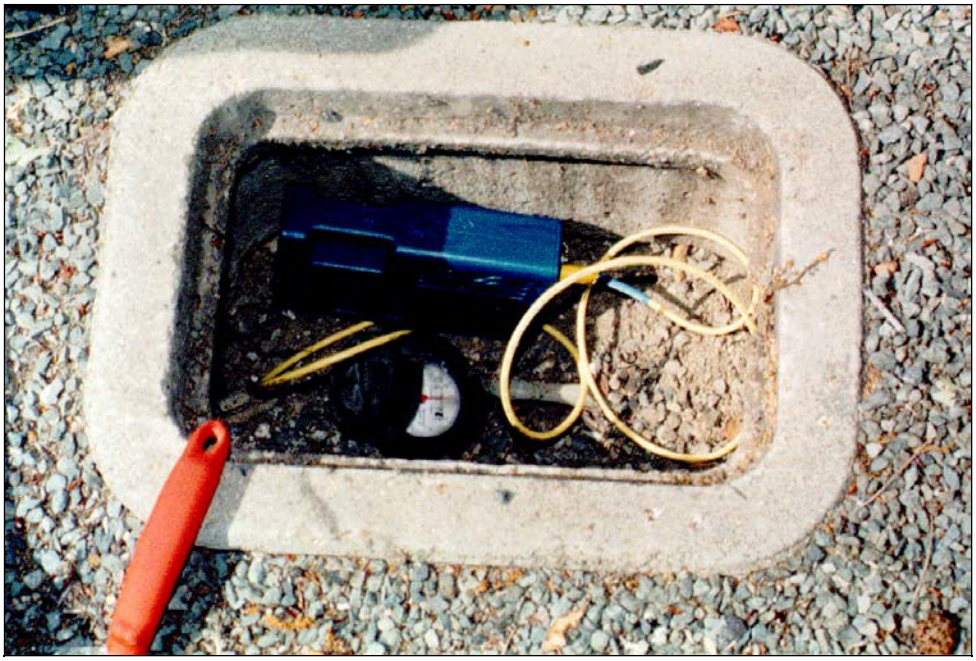

Figure 2: Example of a data logger installed on a residential meter (photo supplied by Aquacraft, Inc.)

The 9 participants (one dropped out half way through the study) went through a thorough water audit prior to participation. Again similar to Phase I, the following components were documented:

- Number of residents
- Any renovations within the past month?
- Any renovations planned within the next month?
- Number of low-flow components (toilets, showerheads, aerators and washing machines)
- Size of landscaped area
- Size of turf area
- Automatic sprinklers?
- Hot water heater temperature setting
- Measured wait for hot water (at the furthest fixture)
- Leak? (including measurement)

Data loggers were then installed (March 2001) for a two week period prior to installation of the system. The participants then had a week to install their system. Once all 9

systems were installed, the data loggers were again placed on the water meters for another two week period. After the five week period, the data loggers were sent to Aquacraft for desegregation. An Access database was then provided to the SCVWD quantifying all uses of water for the 9 participants.

III. DATA ANALYSIS

Phase I

The water consumption of 65 households (25 of the original 90 dropped out for various reasons) was measured for the year preceding and the year following the installation of hot water re-circulation systems. The data consisted of bimonthly meter readings. The populations of meter readings were not normally distributed, but were worse when converted to logarithms. Because of this, analysis was done on the unconverted data. Average household water use decreased by a little more than 2% (approximately 4 ccf/yr) in the treatment year (July, '00 – June, '01) relative to the control year (July, '99 – June, '00), but this difference was not statistically significant (see Figure 1).

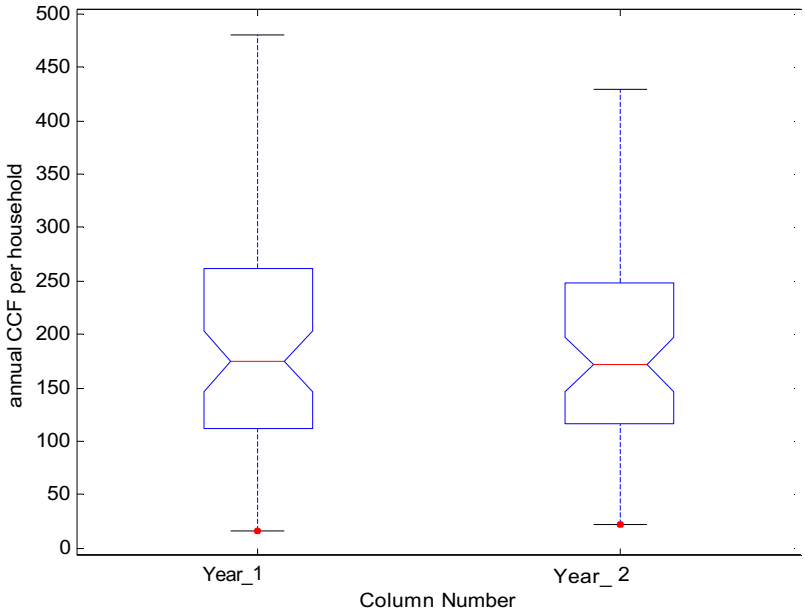

Figure 3: Boxplots for annual household water consumption (ccf)

The boxplots above are a method of representing and summarizing distributions of data. The lower and upper edges of the "boxes" are drawn at the 25th and 75th percentiles of the data. The horizontal lines more or less in the middle of the boxes, in this case in the "notch", represent the sample means of each distribution. The vertical lines extending from the top and bottom edges of the boxes indicate the spread of the remainder of the data, i.e. all those data points lower and higher, respectively, than the 25th and 75th percentiles. The notches are an estimate of the uncertainty about the mean.

It can readily be seen that the upper extreme and the 75th percentile border are lower in the treatment year (Year 2). The mean is lowered almost imperceptibly (4 ccf/year) but the uncertainties surrounding the locations of the true means are nearly identical. The 25th percentile border and the bottom of the distribution are approximately the same amount higher in Year 2 as the mean is lower, reflecting the fact that water consumption actually increased in some (42%) households.

Several other variables were also analyzed to determine if they were significant, including reference evapotranspiration (ET_o), and the annual heat accumulation [as measured by the sum of the bimonthly average maximum temperatures ($^oF_{max}$)]. ET_o was found to be slightly higher in the treatment year (47.54") than in the control year (46.08") while the annual heat accumulation was slightly lower (419 vs. 423 ^oF). Regression analysis indicated that $^oF_{max}$ was most closely associated with water use. Bimonthly average household water consumptions were then normalized to consumption per $^oF_{max}$ and the years compared (Figure 2), but the difference between the years remained insignificant.

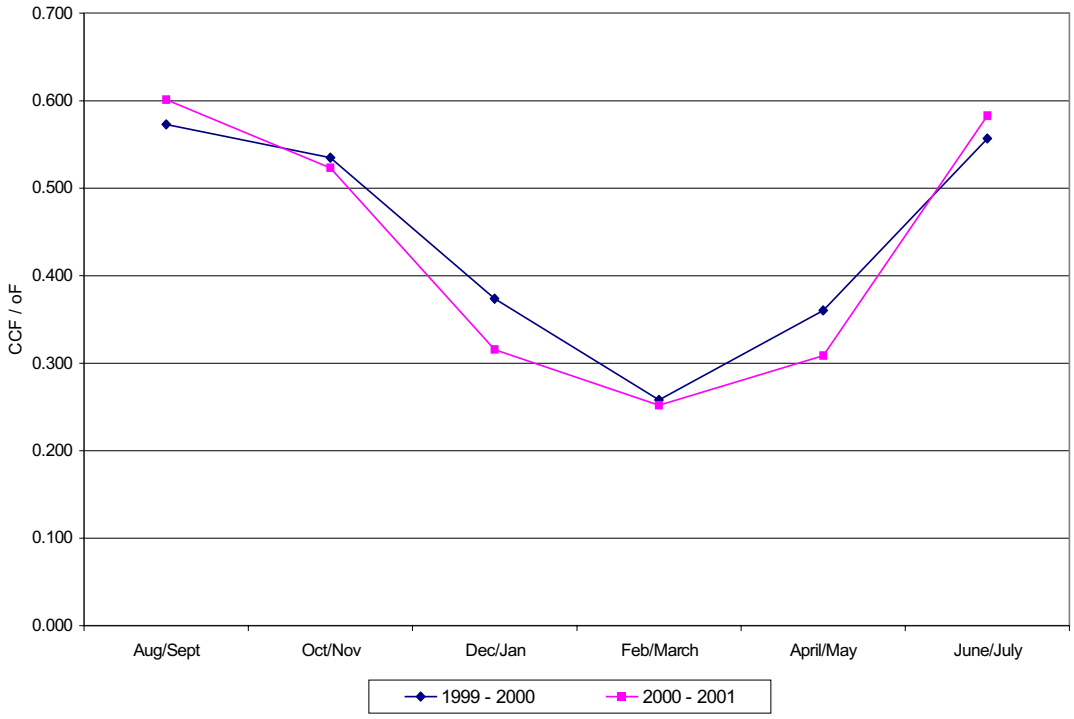

Figure 4: Bimonthly average household water consumption per average maximum daily temperature ($^oF_{max}$)

Finally, an estimate of household irrigation was made by multiplying each household's yard area, converted to acres, by 0.8*evapotranspiration (ET_o). This amount was converted to hundreds of cubic feet (ccf) and subtracted from the bimonthly consumption

data to reduce what was perceived to be a landscape irrigation effect. Again, the comparison revealed no significant difference.

Phase II

Data loggers were installed in nine houses and water use with re-circulation systems was monitored and partitioned for twelve days and compared with a twelve day control period ending a week prior. All "non discretionary" water use such as that due to dishwashers and toilets was removed and the remaining water consumption compared. Discretionary water use decreased 0.6 gallons per person per day following installation of the re-circulation systems, but this difference was not statistically significant.

The discretionary uses under consideration were then limited to showering. Average shower duration increased and volume decreased (0.7 gal/cap/day) following the installation of the re-circulation systems. These seemingly contradictory results may be due to the fact that users no longer had to run showers wide open to flush cold water out of the pipes. These were not considered to be statistically significant.

The average daily maximum temperature was lower during the treatment period than during the control period. The shower data were transformed to duration or volume per average maximum degrees Fahrenheit for their respective time periods, but they remained statistically insignificant.

IV. CUSTOMER SURVEY DATA

SCVWD, in an attempt to understand what the participant's perception of their system was, sent out two customer survey letters (a complete summary of the data can be found in Appendices A and B).

- The first survey was sent out approximately 6 months after installation (October 2000).
- 55 of them were returned - 73.3% return rate.
- The second survey was sent out approximately 1 year after installation (March 2001).
- 53 of them were returned - a 70.7% return rate.

Customers were asked various questions, including rating their system on a scale of 1 to 5 (with 5 being high) as well as how many times a day they use their system. The following figures and table summarize the data collected for theses two questions:

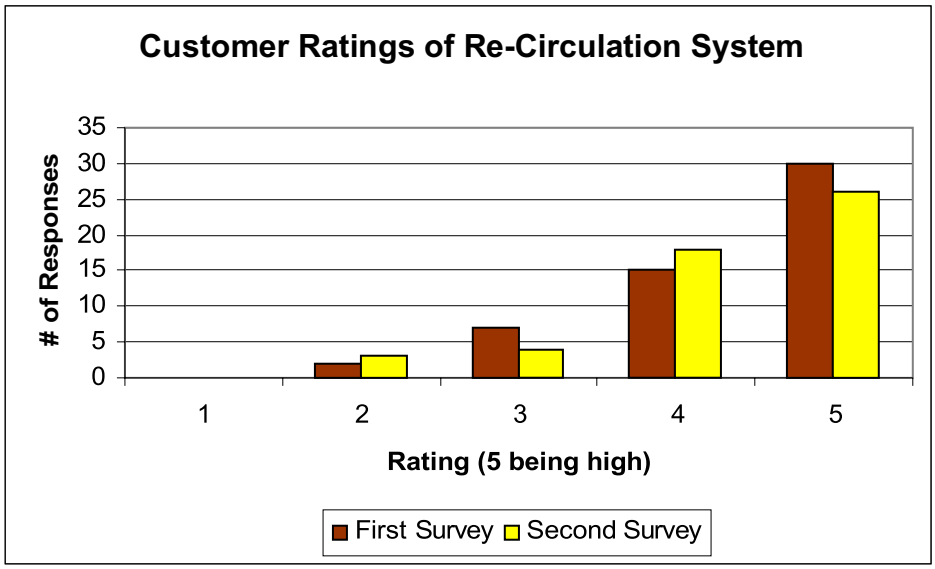

Figure 5: How each participant rated their Hot Water Re-circulation System on a scale of 1 to 5 (with 5 being high)

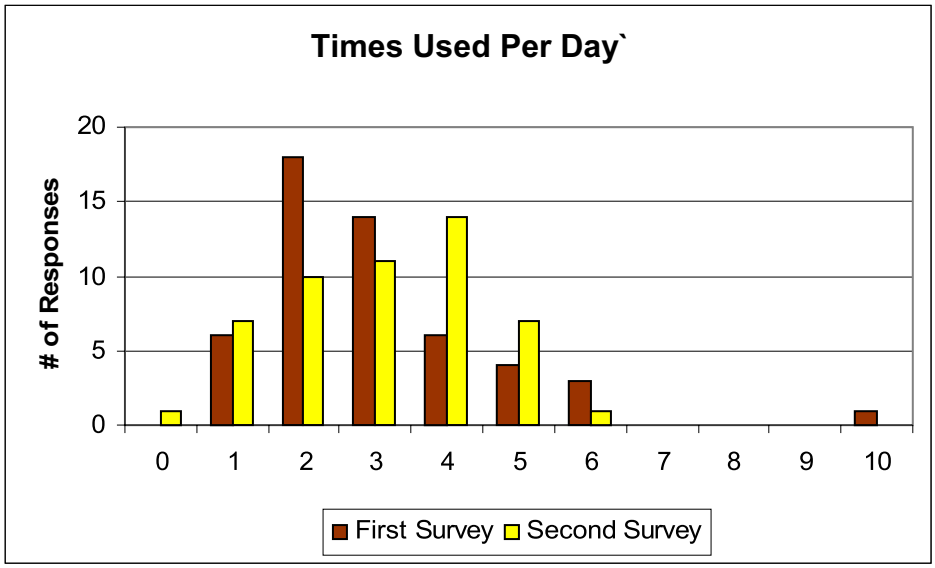

Figure 6: **How many times a day each participant uses their Hot Water Re-circulation System**

Table 2: Average rating and average usage of Hot Water Re-circulation Systems

1st Customer Survey		2nd Customer Survey	
Ave. Rating	**Ave. Times/day Used**	**Ave. Rating**	**Ave. Times/day Used**
4.35	**3.00**	**4.31**	**3.24**

Customers were also asked, in both surveys, what their wait time was for hot water post installation. This was then compared to what was measured in the preliminary screening process. It must be noted that although customers were instructed on how to do this measurement, these ***may*** be the customer's perceptions of what the wait time is post installation and not actual measurements. The following figures and table summarize the data collected:

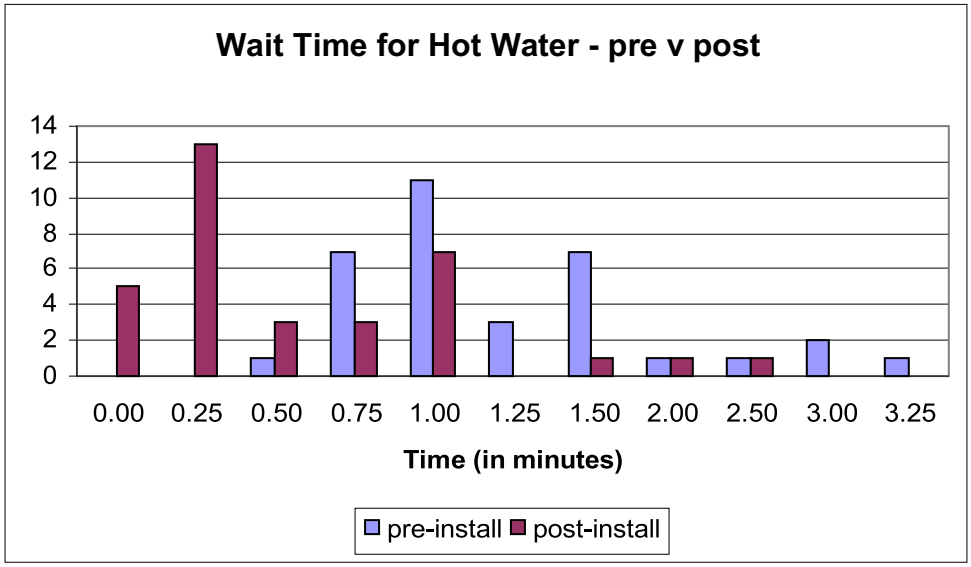

Figure 7: **Comparison of wait time for hot water pre installation versus post installation (1st survey data)**

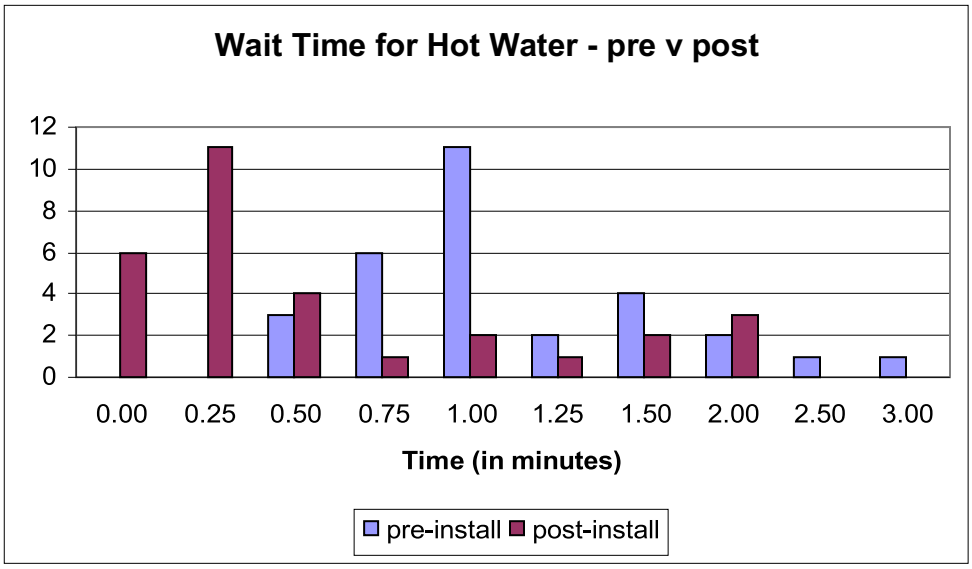

Figure 8: **Comparison of wait time for hot water pre installation versus post installation (2nd survey data)**

Table 3: Average wait for hot water – pre-installation and post-installation

1st Customer Survey		2nd Customer Survey	
Wait pre-install	Wait post-install[2]	Wait pre-install	Wait post-install[2]
1.2 min.	.59 min.	1.2 min.	.61 min.

On the first survey, customers were also asked who installed their system (to gauge how difficult the systems are to install):

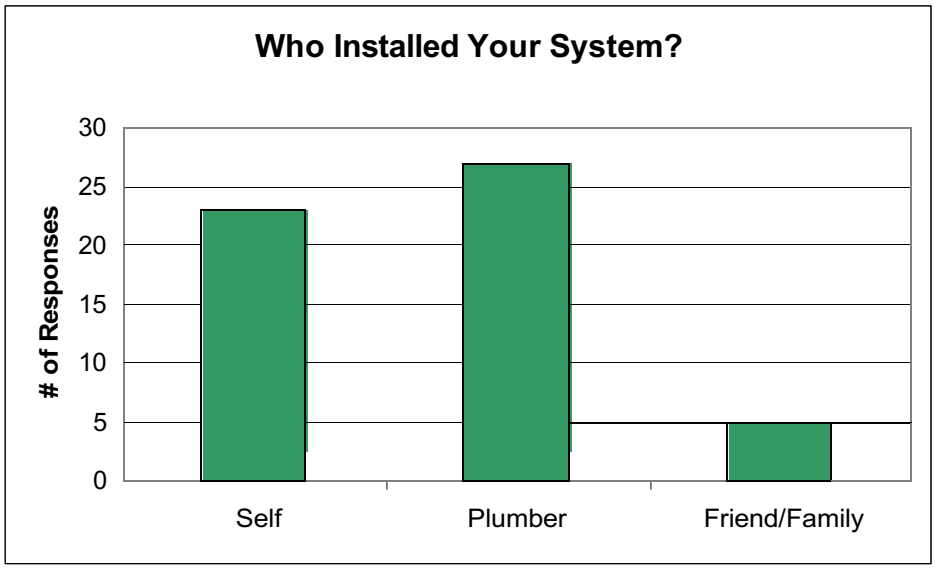

Figure 9: Who installed your Hot Water Re-circulation System?

All participants were initially asked several marketing questions as well, including; who in your household would most likely purchase a new system (both age and gender) and how much would they be willing to pay for a new system. The following figures summarize their answers.

[2] Although the same participants that answered the first survey were not necessarily the same ones that answered the second survey (only 38 of the participants answered both surveys and of those only 23 answered this question on both surveys), the numbers are only slightly different. For those 23 participants, the wait for hot water post installation increases from .63 minutes in the first survey to .69 minutes in the second.

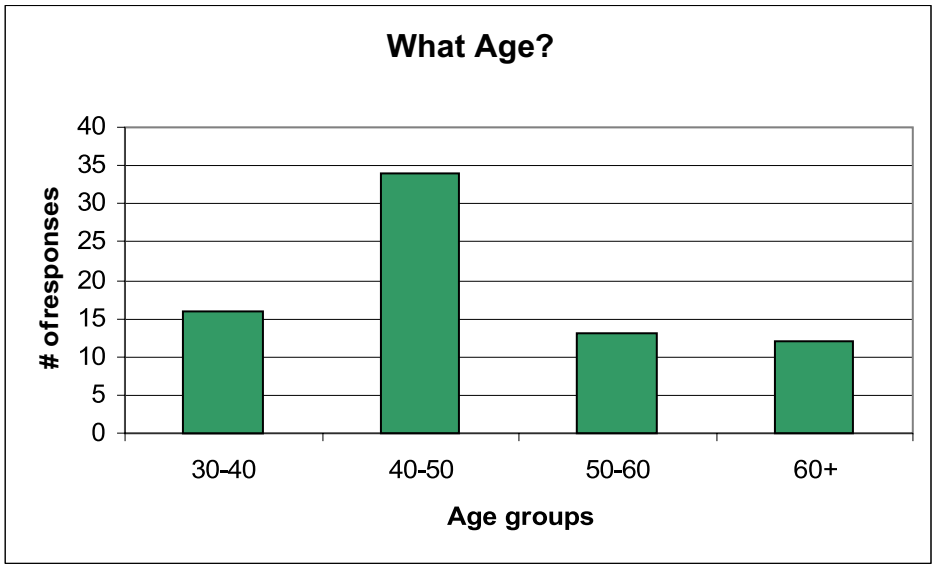

Figure 10: **How old is the person in your household that would most likely purchase a new system?**

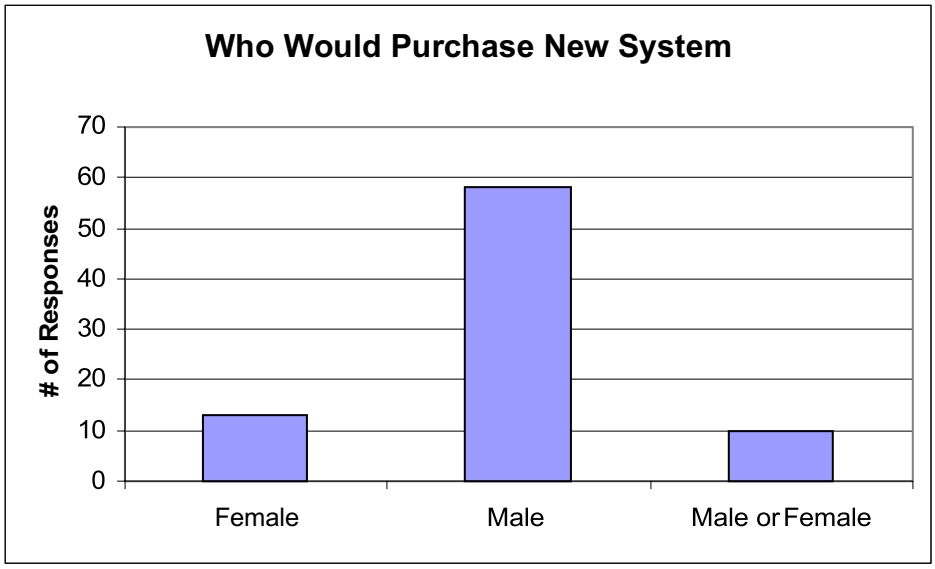

Figure 11: **Who (male or female) in your household would most likely purchase a new system?**

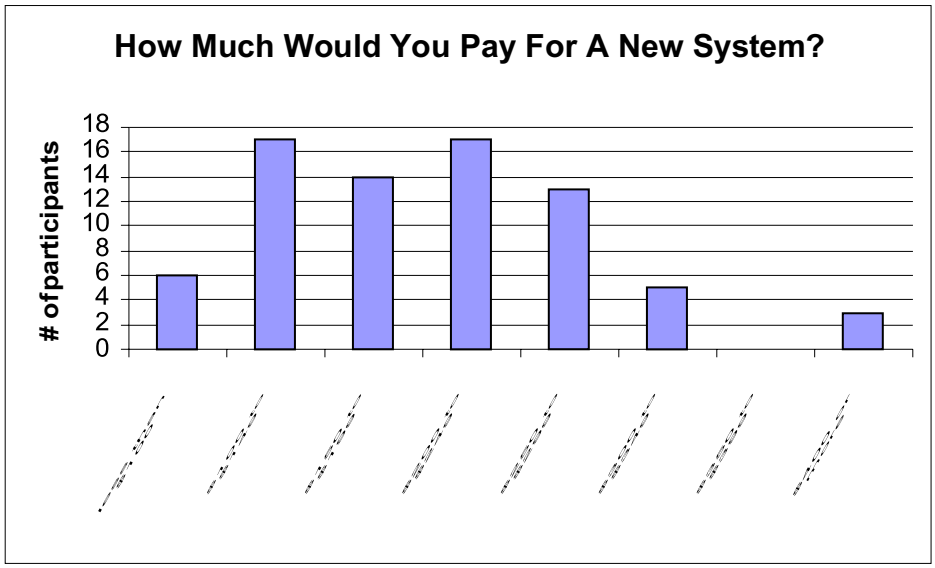

Figure 12: How much would you be willing to spend on a new system?

Finally, each participant was asked how important was it to them that the hot water re-circulation system save money on their energy bill, save money on their water bill, help the environment by conserving resources and make it more convenient to get hot water.

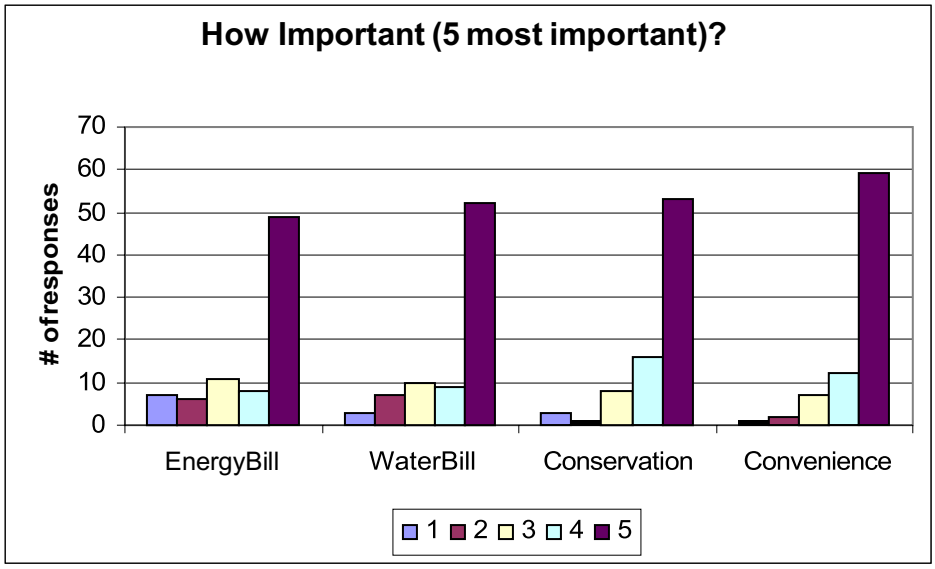

Figure 13: In terms of what motivated you to participate in this study, how would you rate the importance of saving money on your energy bill, save money on your water bill, help the environment by conserving resources and the convenience of getting hot water quicker?

APPENDIX A

Hot Water Recirculation Study Questionnaire 1

Thank you for participating in our Hot Water Recirculation Study. At this time we would like to ask you a few questions. Please fill out the following survey and return it in the envelope provided.

1. On a scale of 1 to 5 (with 5 being the greatest), how happy are you with the system, and why?

1 = 0% 2 = 4% 3 = 13% 4 = 27% 5 = 56%

2. Who installed your hot water re-circulation system (yourself, friend, plumber, etc.)?

Self = 42% Plumber = 49% Friend/Family = 9%

3. To the best of your knowledge, has the hot water heater setting been changed? If yes, what is the new setting?

Yes = 9% No = 91%

4. How many times a day does the system get used?

0=0% 1=11% 2=35% 3=27% 4=12%
5=8% 6=6% 7=0% 8=0% 9=0% 10=2%

5. When does the system get used most? What time of day and for what purpose (showers, baths, sinks, etc.)? Be specific.

Afternoon=5% Mornings=57% Evenings=26% Morn. & Eve.=12%

Showers=48% BathSinks=22% KitchenSink=20% Baths=8% ClothesWasher=2%

6. How long is the wait (in minutes) for hot water once the system is activated?

0=15% .25=38% .5=9% .75=9% 1.0=20%

1.25=0% 1.5=3% 2.0=3% 2.5=3% 3.0=0%

7. Other comments, problems, suggestions, etc?

_____

_____

Name and address (please print) _____

APPENDIX B

Hot Water Recirculation Study Questionnaire 2

Thank you for participating in our Hot Water Recirculation Study. At this time we would like to ask you a few questions. Please fill out the following survey and return it in the envelope provided.

1. On a scale of 1 to 5 (with 5 being the greatest), how happy are you with the system?

   1 = 0% **2 = 6%** **3 = 8%** **4 = 35%** **5 = 51%**

   Has your opinion changed since the last questionnaire? Why?

   Yes = 5% (both increased) No = 95%

2. To the best of your knowledge, has the hot water heater setting been changed since the study began?

   Yes = 20% **No = 80%**

3. How many times a day does the system currently get used?

   0=2% **1=14%** **2=20%** **3=21%** **4=27%** **5=14%** **6=2%**

4. When does the system currently get used most? What time of day and for what purpose (showers, baths, sinks, etc.)?

   Afternoon=7% **Mornings=50%** **Evenings=11%** **Morn. & Eve.=32%**
   Showers=57% **BathSinks=16%** **KitchenSink=16%** **Baths=7%** **ClothesWasher=4%**

5. How long is the current wait (in minutes) for hot water once the system is activated?

   0=20% **.25=36%** **.5=13%** **.75=3%** **1.0=7%** **1.25=3%**
   1.5=7% **2.0=10%** **2.5=0%** **3.0=0%**

6. Have you made any major changes to your landscape within the last year (a new lawn or pool)? If yes, please describe what you did and when you did it?

   Yes = 4% (New lawn and fixed leak) **No = 96%**

7. Have you replaced any of your interior water fixtures within the last year (toilets, showerheads, and/or faucet aerators)? If yes, please describe.

   Yes = 12% (3 toilets, 2 faucet aerators, 1 showerhead) **No = 88%**

8. Has the number of people in your household increased/decreased within the last year? If yes, please describe?

   Yes = 18% **No = 82%**

9. Other comments, problems, suggestions, etc?

   _____

Name and address (please print) _____